Fluoride releasing composites. The effect on secondary caries

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Summary

The demands for aesthetic dentistry and the use of posterior composites are increasing continuously. A major source of failure associated with composite restorations is secondary caries. Secondary caries can be defined as caries developing in the marginal gaps between tooth and restoration due to microleakage and penetration of oral bacteria.

In this thesis two approaches are followed to reduce secondary caries around composite restorations. The first one is the use of fluoride releasing composites. The second one is the application of glutardialdehyde (GDA) on cavity walls <u>before</u> inserting the restoration.

The aims of this thesis as described in chapter 1 were:

-to determine in vitro fluoride release from fluoridating composites,

-to quantify the effect of fluoridating composites on secondary enamel and dentine caries in vitro and in situ,

-to investigate surface changes of composites due to fluoride release and,

-to study in detail the effect of GDA on the dentinal smear layer and on secondary caries in situ.

In chapter 2 a general introduction on dental caries, secondary caries and the effect of fluoride on caries is presented. Epidemiological data show a decline in the occurrence of dental caries. However, secondary caries is still the main reason for replacement of composite or amalgam restorations. Due to secondary caries 40-60% of all restorations need replacement after an averaged period of 7 to 10 years.

Chapter 3 gives a literature survey on current fluoride releasing restorative materials. Fluoridating composites show a considerable fluoride release in vitro. Reduction of secondary caries by these materials has been reported in vitro but extensive investigations in situ or in vivo have not been performed yet. Current composites possess in general good mechanical and aesthetic properties. Silicate cements have also caries reducing properties but have a high solubility and are presently not appropriate for long

term restorative purposes. The popular glass ionomer cements release as well sizeable amounts of fluoride and do reduce secondary caries. However, inadequate mechanical properties limit the use of these materials.
Fluoridating amalgams release negligible amounts of fluoride; in due course these amalgams show strength reduction and enhanced corrosion. Presently, F-releasing amalgams are not useful in clinical dentistry. Fluoridating composites are currently the most promising fluoridating restorative materials.

A new model was developed in order to be able to quantify secondary caries in and around a marginal gap next to composite fillings in situ and in vitro. A simplified schematic illustration of the model is depicted in Fig. 4-1: dental tissue is separated from a composite filling by a gap of 200 μm width.
In chapter 4 the effect of fluoridating composites on secondary caries in situ, in which the fluoride content varied between 0 and 26 vol%, is presented. In the in situ model, enamel demineralisation around the artificial gap next to the composite was quantified by means of transversal microradiography (TMR). The enamel/composite samples were demineralised under plaque in the lower denture of 10 participants for 1 month. In the gap, all fluoridating composites reduced the enamel demineralisation statistically significantly; a reduction of lesion depth and reduced mineral loss values of 25-50% were measured with respect to the non-F control. At the outer enamel surface next to the gap, only the most intensely fluoridating composite showed a beneficial caries reduction. A conclusion of this chapter is that fluoride releasing composites have a local positive effect on enamel demineralisation in situ and are important in future secondary caries prevention.
Long term in vitro fluoride release data from the composites investigated in this work are compiled in chapter 5. The amount of fluoride released in H_2O at 37 °C was followed by fluoride sensitive electrode measurements for a 1 year period. The fluoridating composites released considerable amounts of fluoride into solution ; after 1 year the fluoride release ranged between 0 and 150 $\mu g/cm^2$. The total amount of

fluoride released as a function of time t from the composites was found to be proportional to log t or to t depending on the type of the fluoridating filler system.

The in vitro fluoride release data were correlated with the in situ demineralisation data, both after 1 month. A linear correlation was found between the in situ demineralisation values and the logarithm of the in vitro fluoride release. A fluoride release of 200-300 $\mu g/cm^2$ per month would completely inhibit enamel demineralisation around restorations. As the caries reduction induced by F-composites was found to be proportional to the log of the fluoride amount released, it is concluded that secondary caries is more effectively decreased by a long term low rate F release than by a high rate short term release.

The effect of fluoride release on potential surface degradation of the fluoridating composites has been estimated in chapter 6. The composite samples were placed in situ under plaque for 1 month or in water at 37 °C for 1 year. Two experimental techniques were used to measure the surface changes: 1. the Knoop surface microhardness technique, and 2. scanning electron microscopy (SEM). Two different types of microhardness measurements were performed. In the first type, initial indentations were made and measured; after a given time the indentation lengths were remeasured. In the second type, new indentations were made after a given time interval and again measured immediately. The results show that all composite surfaces are significantly softened in vitro; the similarity of both fluoridating and non-F composites indicate that fluoride release obviously does not play a role in surface hardness changes. Using the same techniques on the in situ treated samples gave spectacular differences: the surface hardness of the fluoride releasing composites did not change but this parameter increased in case of the non-F composite. An explanation for this behaviour is that in situ the presence of the pellicle likely influenced the transport of water and of ions in and out of the composite and thereby affected the surface microhardness. These differences in surface hardness (not reflected in the SEM micrographs) are limited to the outer few μm of the composite materials.

In chapter 7 the effects of fluoride releasing composites on secondary caries in vitro as a function of time are presented. Dentine demineralisation around a marginal gap of 200 μm width next to a composite filling was quantified using wavelength independent microradiography (WIM). Compared with the TMR technique, which permits only one mineral assessment, the non-destructive WIM allows the possibility to perform repeated mineral measurements as a function of time t. Another advantage of WIM is that the de- or remineralisation of whole dentine or enamel blocks is quantified. One result is that a fluoridating composite reduced the dentine demineralisation in the gap by approximately 50% after 8 weeks. The mineral loss values show a linear correlation with time, which indicates that a long term caries reducing effect from fluoride releasing composites on dentine can be expected.

The second approach to reduce secondary caries mentioned previously is the use of GDA (2% solution, pH 3.5) on dental tissue is described in chapter 8. In the in situ model demineralisation of enamel and dentine around a gap of 200 μm width was quantified by means of TMR after 1 month. A 2-min application of the GDA solution reduced dentine demineralisation substantially; a reduction of mineral loss values of 30% was demonstrated. The GDA treatment, however did not beneficially affect enamel demineralisation. The reduction of dentine demineralisation is due to the reaction of GDA with collagen resulting in superficial GDA fixation of the dentine. The 'GDA-changed layer', also discussed in chapter 9, decreases the diffusion of calcium and phosphate out of the dentine lesion and influences the caries process.

In chapter 9 the effect of the GDA treatment on the smear layer present on human dentine was investigated by means of SEM. The main result of this part of the investigation is that more than 50% of the dentinal tubules of GDA treated dentine remain closed after EDTA application. [EDTA is known to completly remove the smear layer and open up the tubules.] Fixation of the superficial dentine surface and parts of the smear layer, and the closing of dentinal tubules by GDA has a positive effect on dentine (root) caries in situ and in vivo. GDA probably also reduces dentine hypersensitivity.

In the general discussion in chapter 10, a survey is given of the combined results of this work as fluoridating composites are concerned. This chapter evaluates the fluoride release of the composites in situ by considering the formation of surface layers covering the enamel lesions next to fluoridating and non-F composites and the F-gradients build up in these lesions. The F-gradients were measured by using secondary ion mass spectrometry (SIMS). The relations between F-uptake and surface layer formation are discussed. A conclusion of this part is that the amount of fluoride released in the liquid in the gap is much more effective in lesion reduction than the amount of incorporated fluoride in the dental tissue. In the end of this chapter attention is given to the differences between in vivo and in situ experiments and to future developments.
From this study it can be concluded that fluoridating composites effectively reduce secondary caries in situ. The fluoride release from composites probably increases the longevity of composite restorations which is of great clinical relevance.